The State of the

DØ Silicon Tracker

DØ Collaboration Meeting

January 14, 2000

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Fermilab

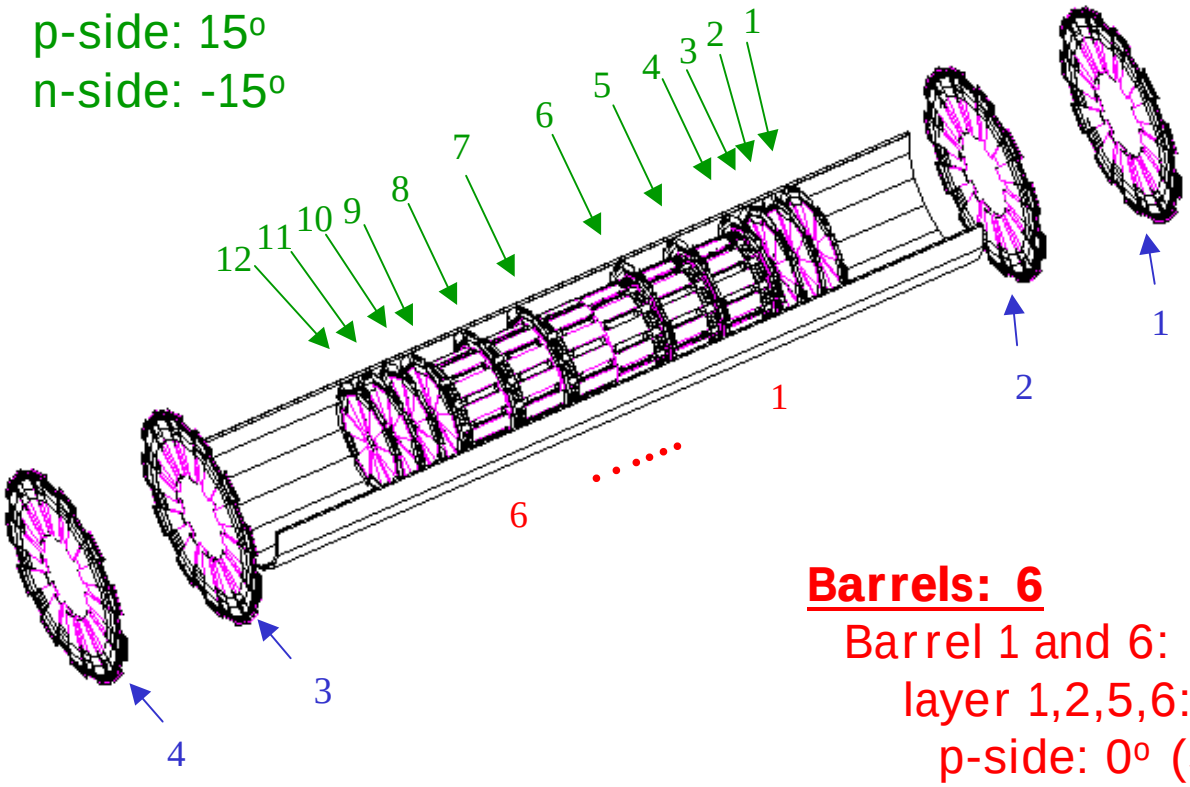
Outline

- DØ Silicon Microstrip Tracker
- Production Line of the silicon detector
- Production Status
- Testing Status
- Silicon Read Out
- Fallback
- Conclusion

DØ Silicon Microstrip Tracker

F Disks: 12

p-side: 15°
n-side: -15°



H Disks: 4

p-side: ±7.5° (SS)

Barrels: 6

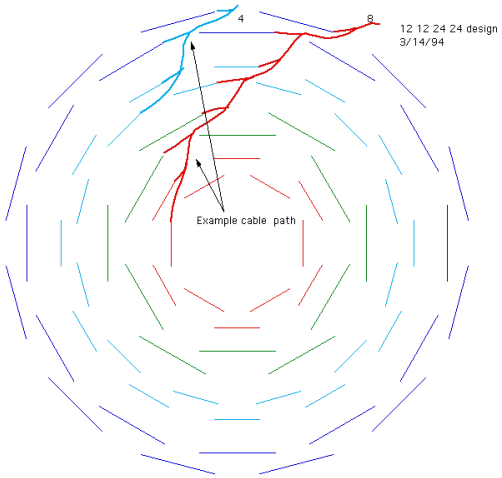
Barrel 1 and 6:
layer 1,2,5,6:
p-side: 0° (SS)

Barrels 2, … 5
layer 1,2,5,6:
p-side: 0°
n-side: 90°
layer 3,4,7,8
p-side: 0°
n-side: 2°

	Barrels	F-Disks	H-Disks
Channels	387120	258048	147456
Modules	432	144	96
Inner R	2.7 cm	2.6 cm	9.5 cm
Outer R	9.4 cm	10.5 cm	26 cm

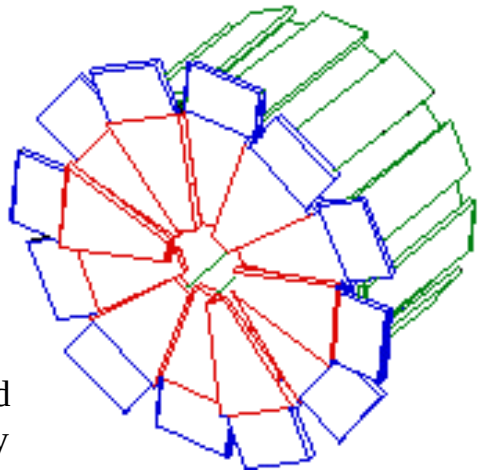
DØ Silicon Microstrip Tracker

- 5 different detector types
  - Barrel:
    - » 72 Single Sided ladders, axial (3-chip) (Outer Barrels only)
    - » 144 Double Sided, axial / 90^0 (6-chip)
    - » 216 Double Sided, axial / 2^0 (9-chip)



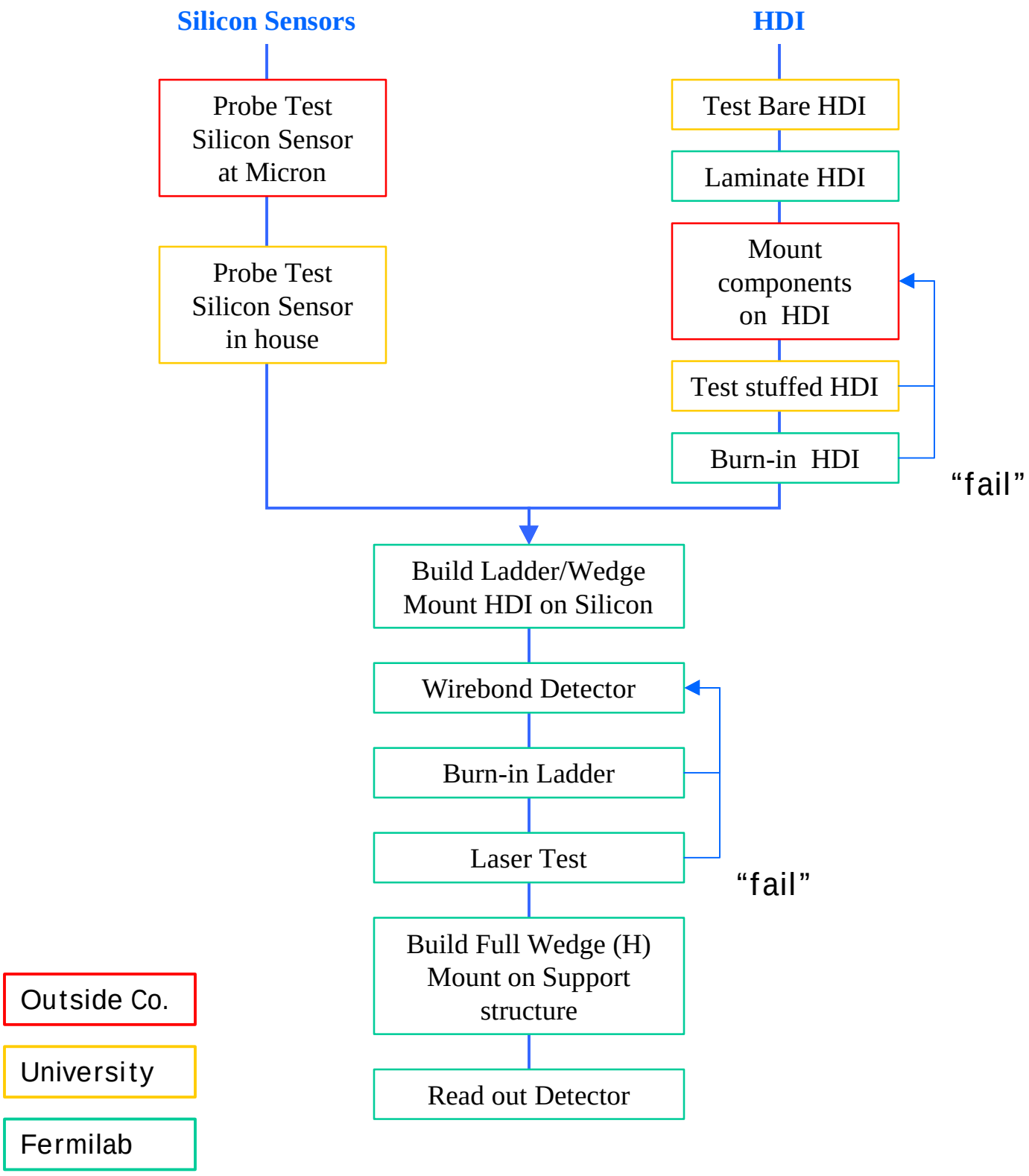
R-z view, 8 layers cable routing

  - Disks:
    - » 144 Double Sided F disks (6+8 chip)
    - » 96x2 Single Sided, back-to-back H disks (6 chip)



View of F disk mounted on Barrel/disk assembly

Production line of Silicon Detector



Silicon Sensors

Barrel

- Axial detectors (3-chip):
  - Need to order 20 more sensors $14k
  - No delivery problems
- 90^{o} detectors (6-chip):
  - First batch of sensors had defects (p-stop touches n+ implant); each device visually scanned
  - currently ~60 sensors in hand (144 needed) but problems with noise
  - Micron delivery remains worrisome (~12/month)
  - Need ~10 sensors/week to complete detector
  - Huge (~600) number of sensors in production line, but Micron staff is stretched thin.
    - » We appealed for help on Dec 9, 99
    - » Our Czech collaborators offered to station on average 1.5 people at Micron to help with testing devices on site for 6 months
    - » On Jan 10, 00 our Czech collaborator at Micron

Thank you !!

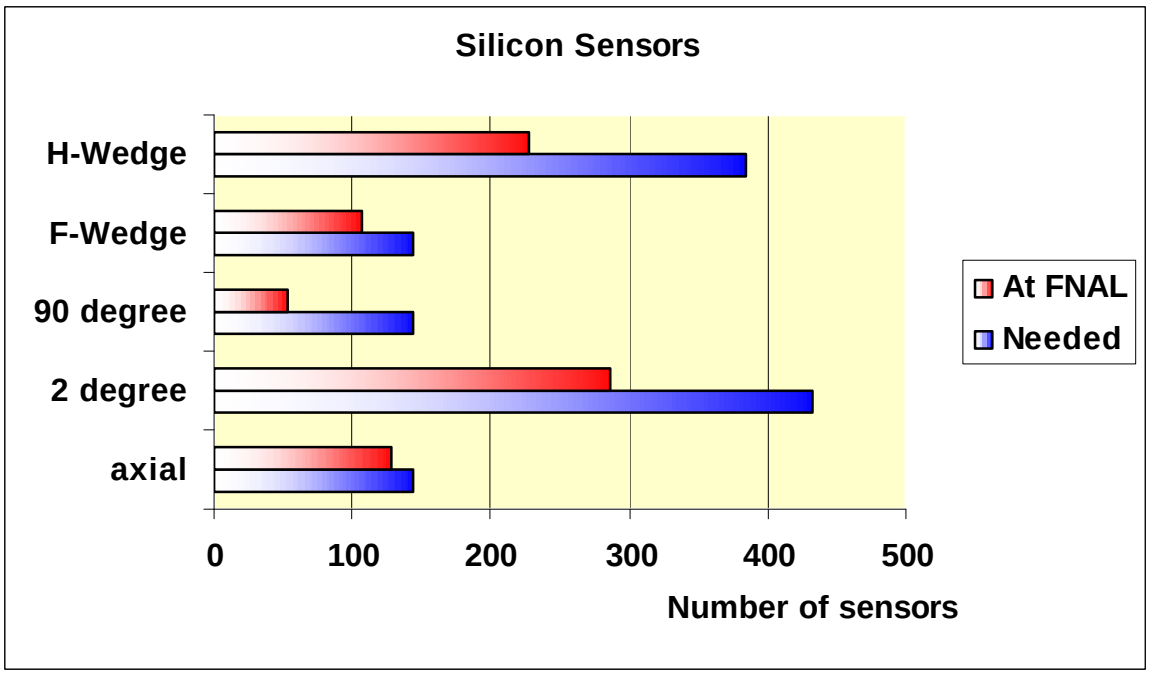
  - production will be paced by Micron delivery
  - production schedules may force us to accept lower grade devices

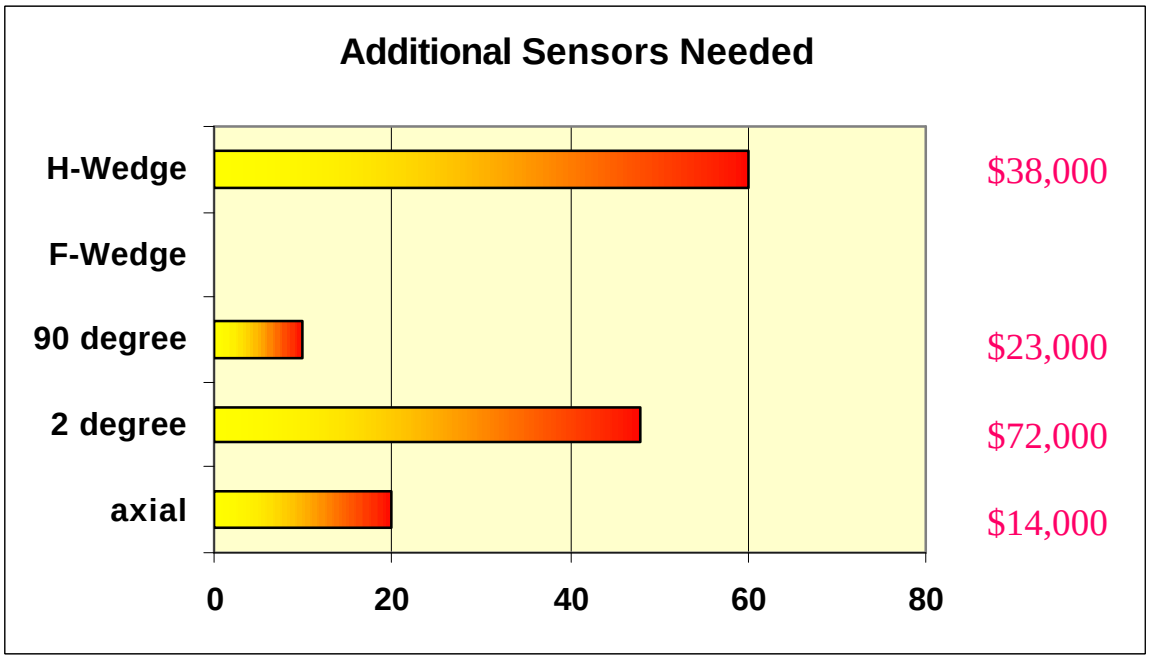
- 2º detectors (9-chip):
  - sensor production proceeding well
  - Full delivery of order anticipated in April
  - Need to order 48 additional sensors $72k

Disks

- F Wedges:
  - Proceeding okay at yield of 50-60% at Micron
  - Currently 43 wafers in production, 25 needed
  - Completion of order for 125 detectors expected by March
  - First of order for 75 sensors from Eurisys received
    - » larger bias resistance than specified (add SiO_2 layer)
    - » lower breakdown voltage (60-80V) (change p-implant concentration)
  - Timely delivery is anticipated
- H Wedges:
  - due to larger than expected use of devices for prototyping 60 additional sensors need to be reordered to complete full H disk $38k

Summary of Sensor Status



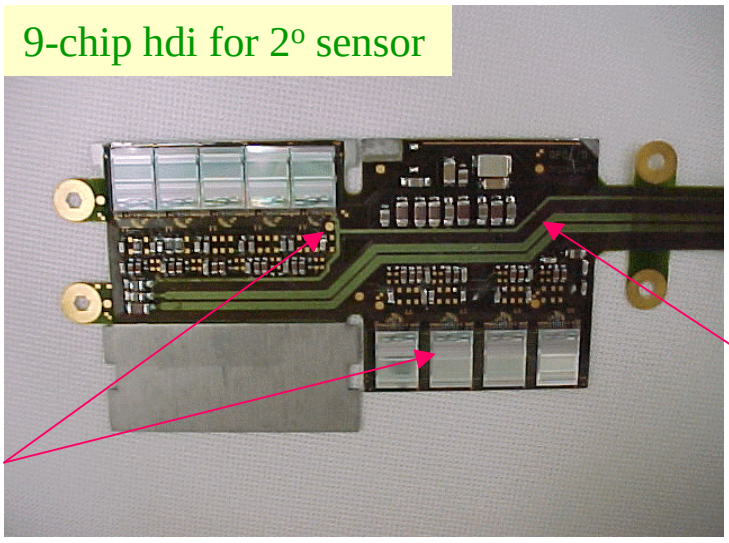


- All sensors are in production line. No delay in module production anticipated due to purchase of additional sensors, except for 90° sensors.

High Density Interconnect (HDI)

- Flexible Kapton/Cu circuit
- Laminated to Be substrate and glued to Si sensor
- Provides read out of Silicon
- Connects Si to SVX chip and SVX chip to flex circuit trough wirebonds
- connects to low mass cable which carries signal out of the detector

9-chip hdi for 2º sensor



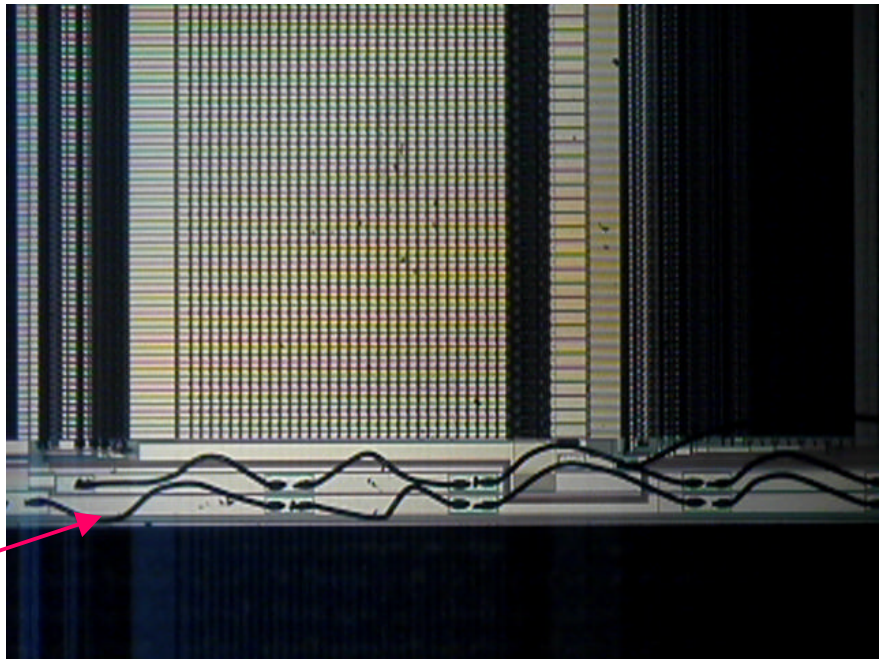
SVX II E chips

bus control and power traces

- hdi's obtained from a variety of vendors (Dyconex, Speedy, Compunetics)
- Tested at CSUF and laminated at Fermilab
- F Wedge hdi especially intricate device
  - 2 hdi's glued back to back
  - additional jumper (pitch adapter) for 6 chip side (n-side) from different vendor (Max Levy)

Component Mounting of HDI

- Surface mount and chip bonding done at Promex (CA)
- Multitude of problems
  - weak wirebonds, pull strength 2 grams (7 nominal)
  - wirebonds don't stick
  - hdi's rejected by company
  - poor quality of work performed
    - » poor wirebonds
    - » no dye attach
    - » chips don't download
    - » shipping disasters
  - ... ...
  - Recently lost 14 F wedge hdi's
- Qualifying alternate vendor, Silitronics (Connor-Winfield)



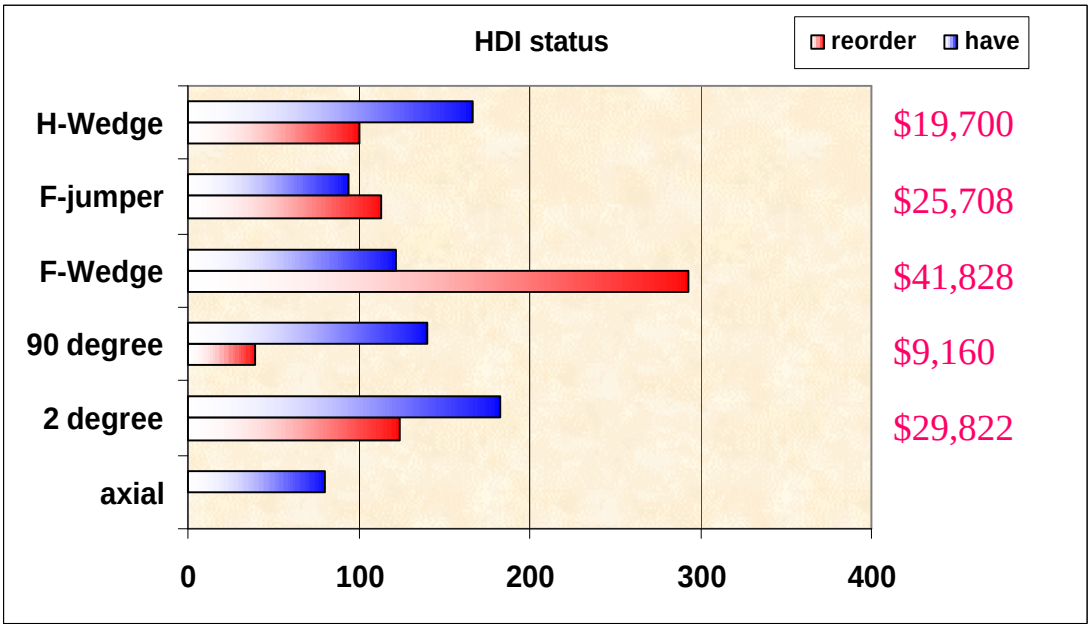
Poor wirebonds

hdi yields

- The Si group tries to provide oversight at the companies while hdi's are being stuffed, but …
- overall yield fluctuates: 60-90%

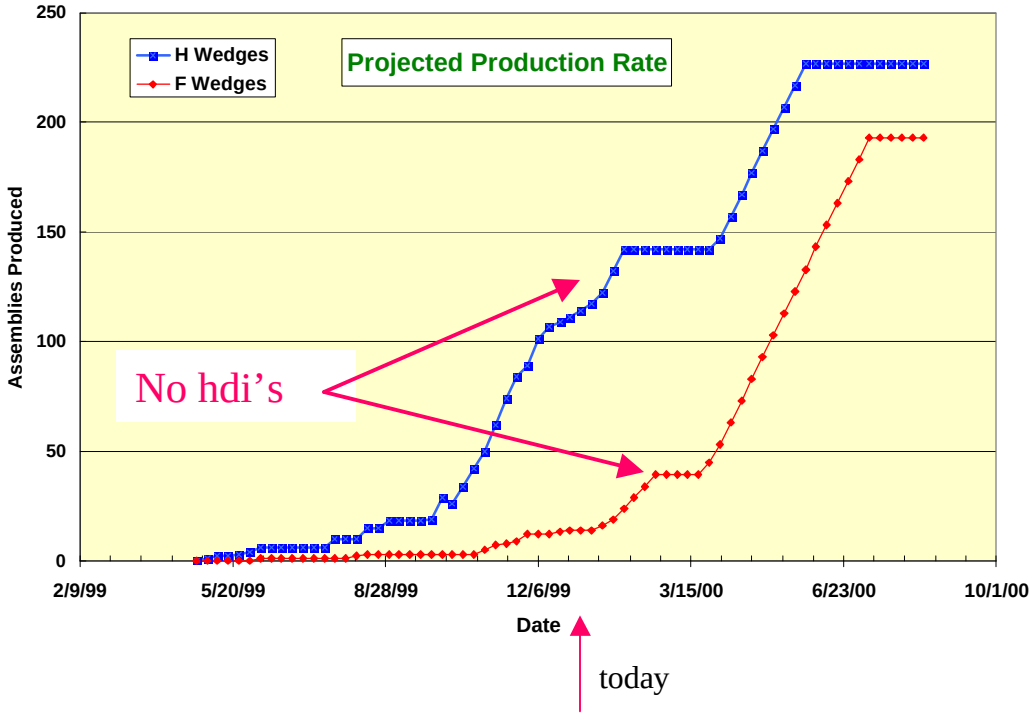
	hdi probing	lamination	stuffing	overall
9-chip	0.95	0.97	0.80	0.74
6-chip	0.93	0.95	0.85	0.75
F-disk	1.00	0.90	0.80	0.72
H-disk	0.90	1.00	0.78	0.70

- Because of the low yields, additional hdi's will have to be reordered to complete the detector



Implications of additional hdi purchase

- Significant strain on budget
- Significant impact on production schedule
  - F wedge production
    - » F wedge production projected to be halted for one month in March due to non availability of F wedge hdi's
  - H Wedge production
    - » H wedge production projected to be halted for one month in February due to non availability of H wedge hdi's (but not a problem since effort is diverted into building of full wedges)



- Significant impact on availability of hdi components

SVXII E Chips

- Main component mounted on hdi is SVX chip
- Manufactured by UTMC, no longer in business
- LBL will deliver 4348 svx chips from last batch
- Additional 39 wafers banked with 148 chps/wafer
- With yield of 60% gives 3450 additional chips
- Fiber tracker needs 1000 chips
- Total of 6800 chips available for remaining hdi's

chips needed to complete Si

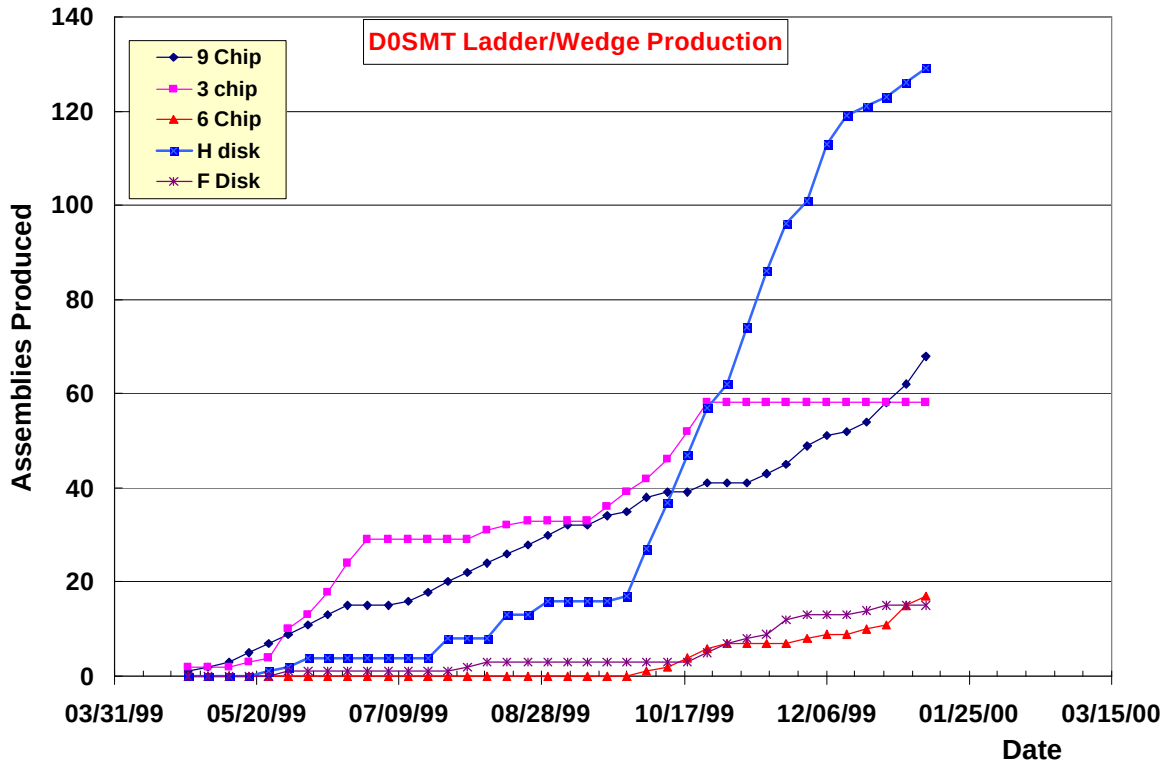
	for hdi's at hand	for hdi's to reorder	total
3-chip	60	0	60
6-chip	240	240	480
9-chip	720	1116	1836
F-disk	700	3000	3700
H-disk	120	600	720
Total	1840	4956	6796

- Note, these numbers have a large margin of error
- Conclusion: we are on the hairy edge.
- As preventive measure, chips will have to be recovered from broken hdi's; has not been tried to see if it can be done at all.

Ladder and Wedge Production

- Axial detectors (3-chip):
  - 58 ladders built to date, 72 needed
  - Production halted:
    - » effort diverted to 2º detectors
    - » no hdi's available
  - Can complete full complement of detectors in 3 weeks
- 2º detectors (9-chip):
  - Production lagged due to qualifying of fixtures
  - Fourth and last fixture should be qualified this week
  - Eliminated one glue cycle from production
  - Currently building 2 ladders/day which can go up to 4 ladders/day
- 90º detectors (6-chip):
  - One fixture qualified with production of 1 ladder/day
  - Second fixture being qualified and two additional on order
  - A second production line in Lab A has been set up with one CMM, to be extended to two CMM's
  - Production will be limited due to:
    - » Micron sensor delivery, built ladders when sensors sent
    - » Inspecting, probing and testing of sensors
    - » Schedule may impose acceptance of lower grade devices
- F Wedges (14-chip):
  - Limited by availability of hdi's
  - Current rate 1/day, go to 2/day
- H Wedges (6-chip):
  - In steady production, 2/day

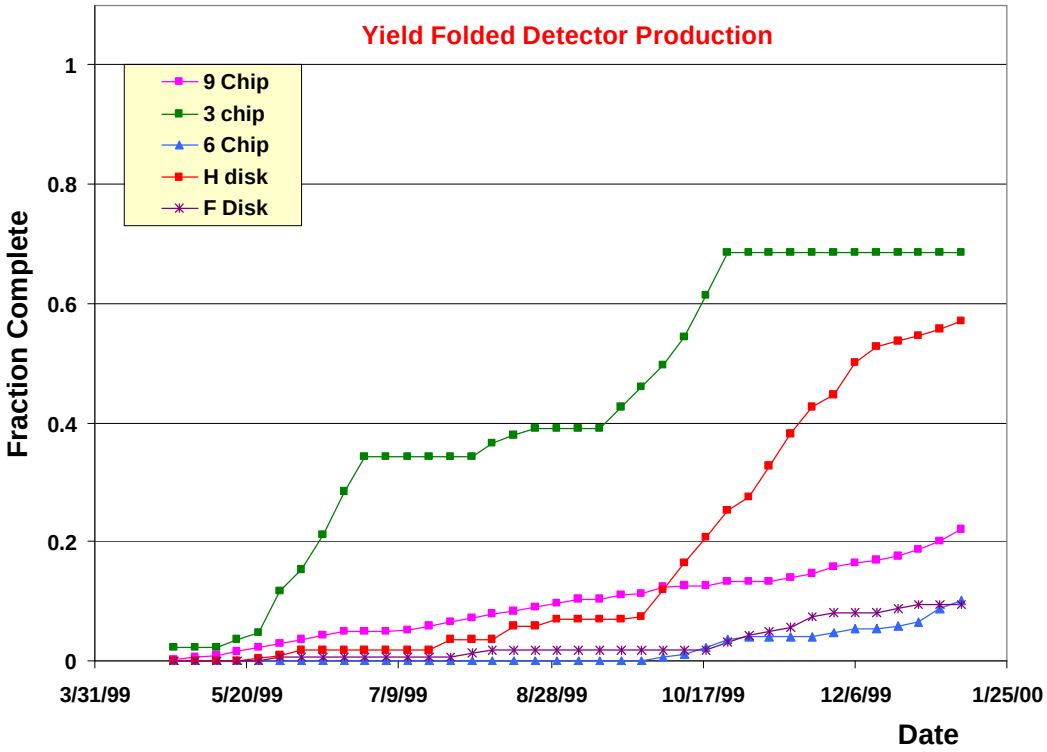
Production Status



	9 Chip	3 chip	6 Chip	H disk	F Disk
Produced	68	58	17	129	15
Needed	216	72	144	192	144
To go	202	27	152	97	145
Yield	0.80	0.85	0.85	0.85	0.90

Note: In above graph, yield not included.

Production Status, yield folded



- Assumed Yields:
  - 9-chip: 80%
  - 3-chip: 85%
  - 6-chip: 85%
  - H-wedge: 85%
  - F-wedge: 90%

Additional orders

- Mentioned we need additional sensors and hdi's at a total cost of ~$300,000

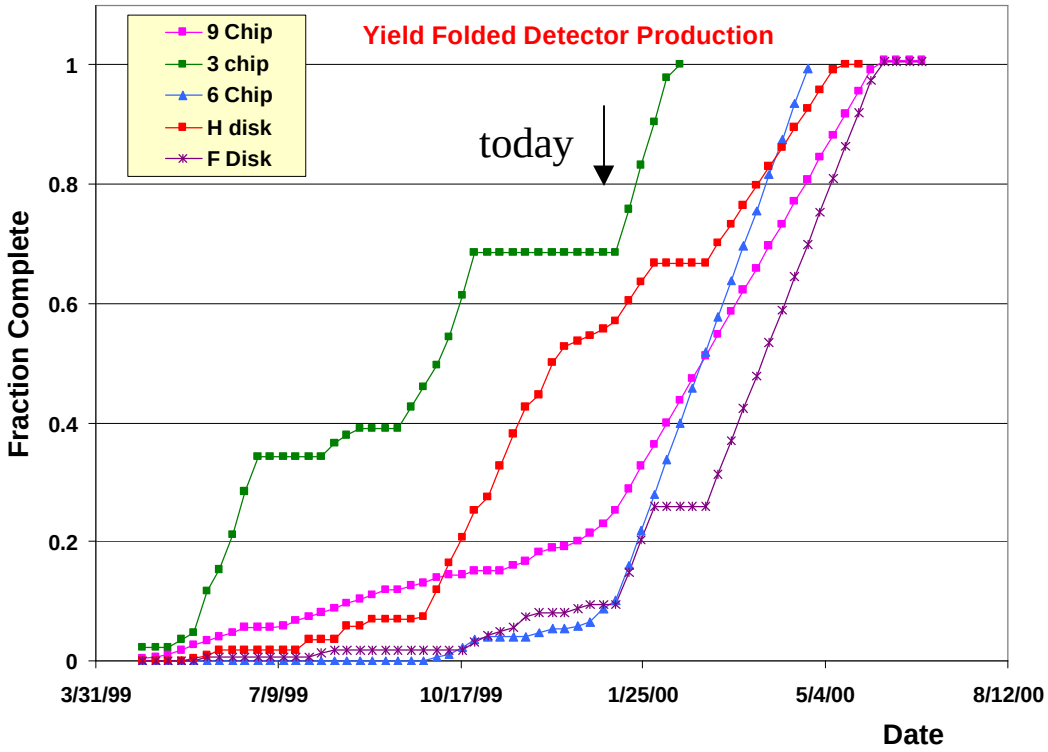
  Where do we stand if the additional parts are not purchased?

  - 4 barrels worth of 2^o detectors
  - 3 barrels worth of 90^o detectors
  - 3.5 F disks
  - 3.5 H disks

- But, assume the purchases do get approved, what does the production rate have to be?

Projected Production Rate

- Extrapolate to Milestones:
  - 2/11/00 3-chip ladder production complete
  - 4/27/00 6-chip ladder production complete
  - 6/22/00 9-chip ladder production complete
  - 6/7/00 F wedge production complete
  - 5/14/00 H half wedge production complete



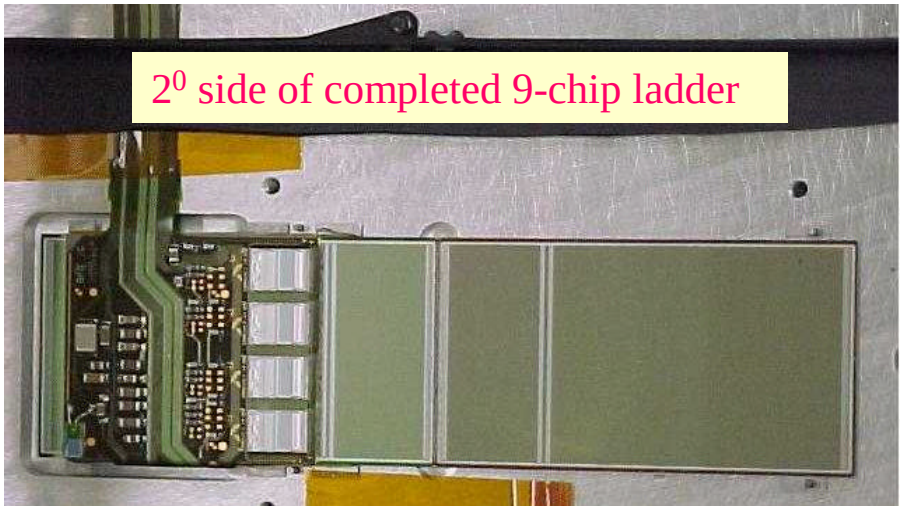
	Yield	Production Rate
– 9-chip:	80%	10/week
– 3-chip:	85%	6.2/week
– 6-chip:	85%	10.2/week
– H-wedge:	85%	7.3/week
– F-wedge:	90%	8.8/week
– Total:		42.5/week

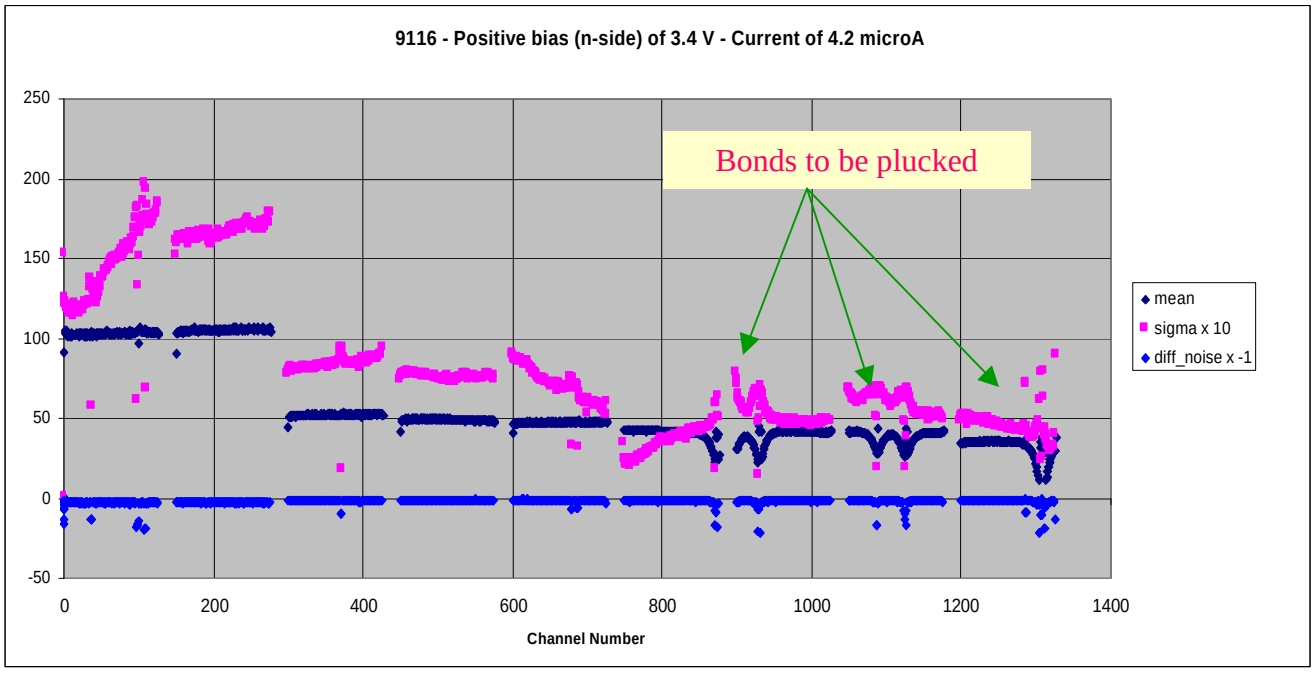
Production Summary

- Production effort needed is enormous but, I believe, feasible
  - Micron issues addressed
    - » 2 people permanently at Micron for duration
    - » 90 degree sensors remain very critical
  - Can increase 9-chip ladder production to 20/week
  - Set up second production line in Lab A for 6-chip ladder production. Could go to ~20/week
  - Addressed as is reasonably possible stuffing of hdi's
  - Created Engineering Physicist Opening to help with ladder production and engineering; offer out
  - Trying to recruit additional person
  - Added new fast wirebonder (8090)
  - Added 3 technicians to production
  - Added 2 new technicians for wirebonding
  - ……..
  - ……..

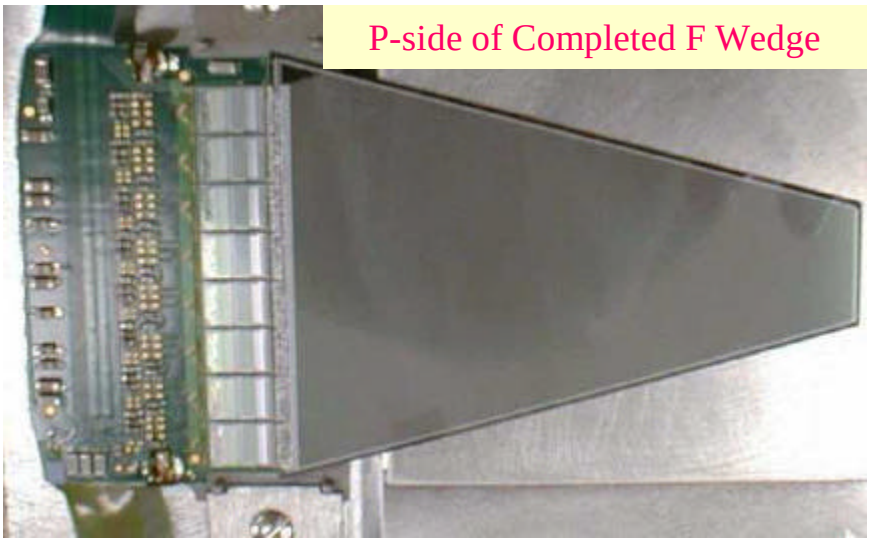
After the detectors have been built

- Detector debugging
- Detector repair
- Detector burn in
- Laser Test
- Read out





Testing and Repair



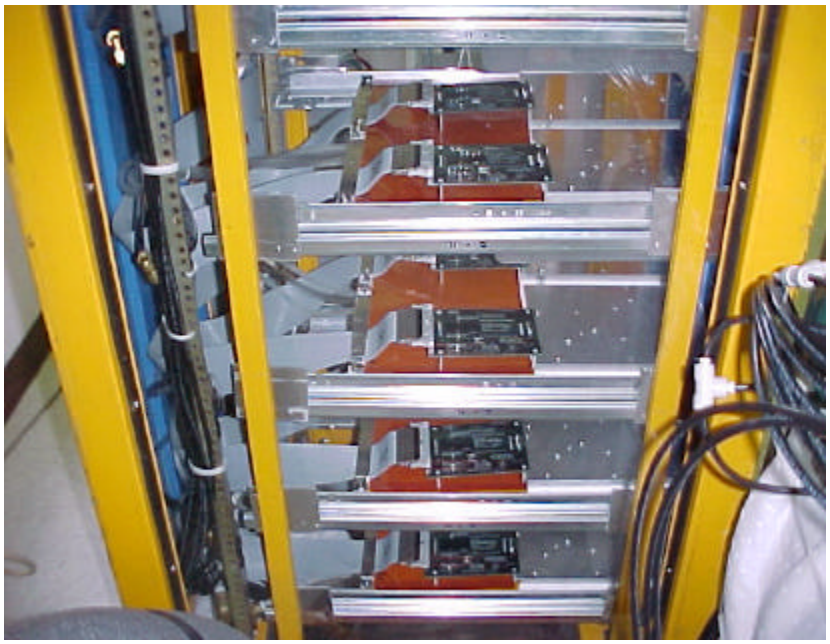
Each F Wedge has more than 2500 wirebonds

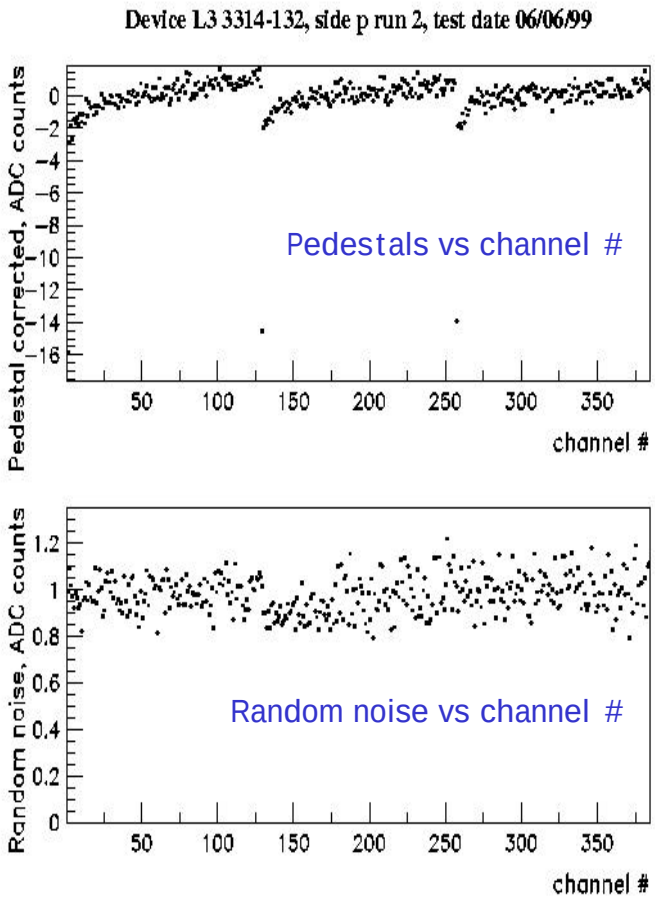
- Debugging and repair is iterative process
- Pluck bonds corresponding to noisy strips
- Re-evaluate detector
- Very time consuming; problem devices can easily take >1 day to debug

- All devices have to be tested and debugged
- Serious shortage of manpower; need dedicated crew of people

Burn-in

- Detectors biased, cooled
- Measure pedestal, gain, noise and sparse readout
- Done very effectively by shifters

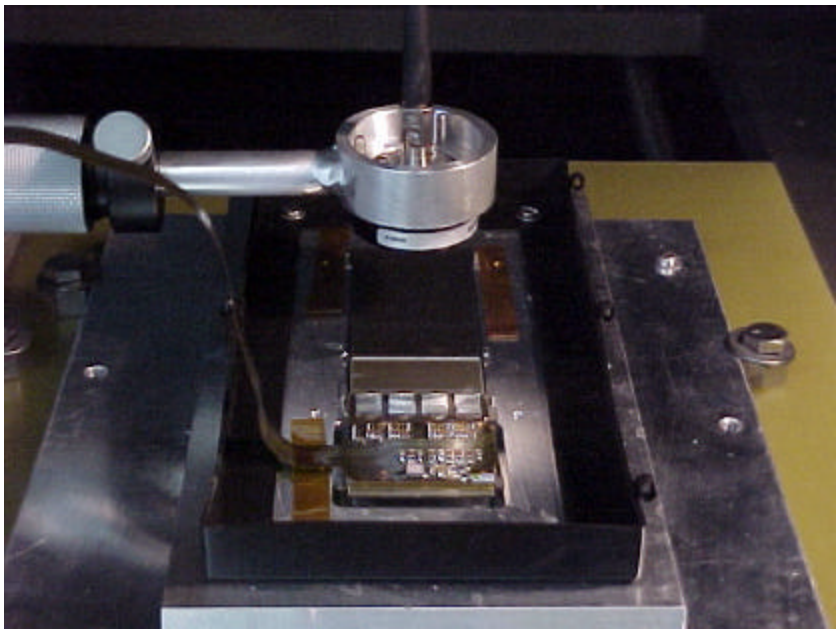


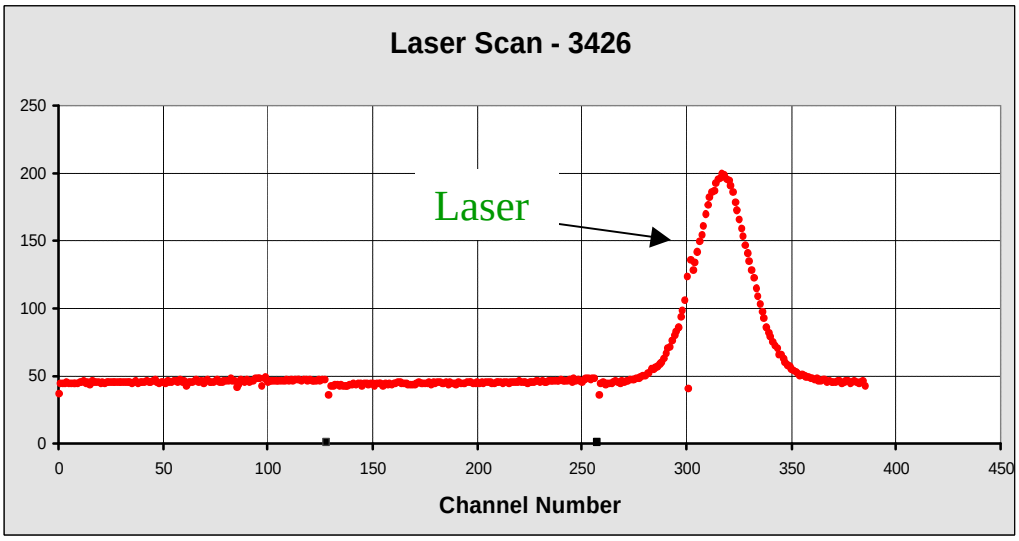


- 40 detectors per week need to be burned in
- Relevant data needs to be stored in database
  - pedestal
  - noise
  - gain
  - dead channels

Laser Test

- Detectors biased
- Exposed to narrow laser beam
- 40 detectors per week





- Measure depletion voltage
- leakage currents
- dead channels
- …… store information

- Started this week with shifters
- Can be very effective

Infrastructure

- Current Test stands: 7
  - two test stands for burn in (PC3, PC6)
  - two test stands for laser test (PC2, PC7)
  - one debug (Lab D), one repair (semi), one multipurpose test stand
- Future Test stands:
  - one additional burn-in test stand
  - one additional debug test stand (Lab D)
  - one additional small scale full read out system

All infrastructure is in place, but test stands need to be manned

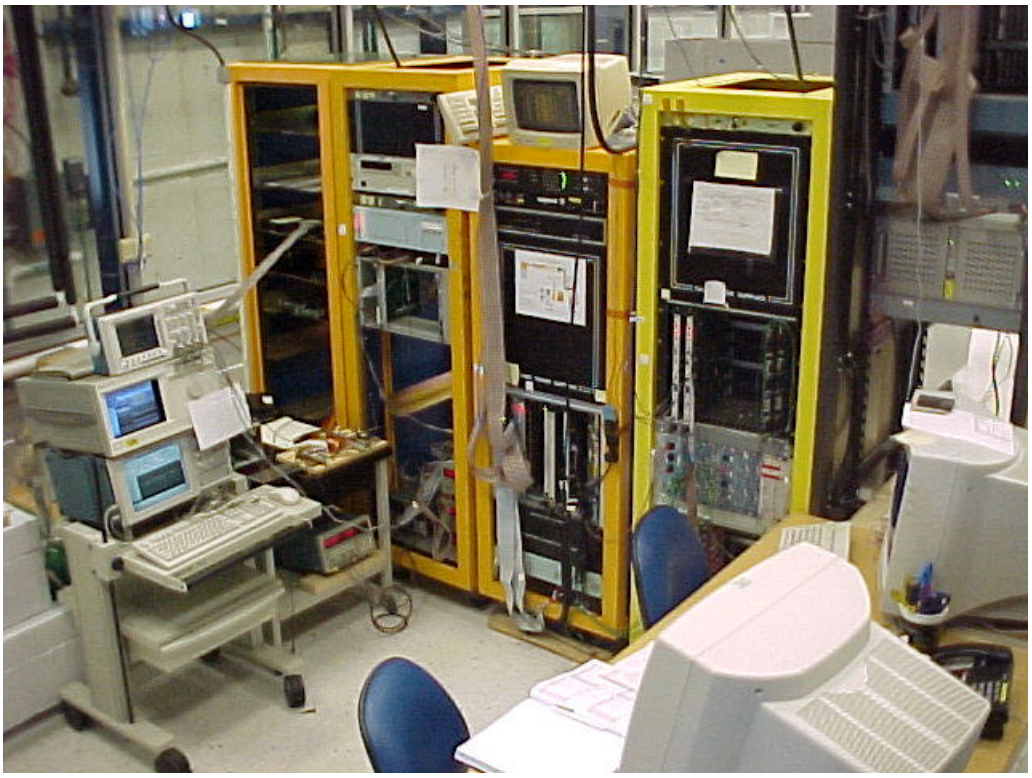
Remember:

- 40 detectors produced per week
- need to be tested / debugged / repaired
  Arduous process!!
- Detector burn-in
- Detector laser test
- Analyze and evaluate data
- Store information

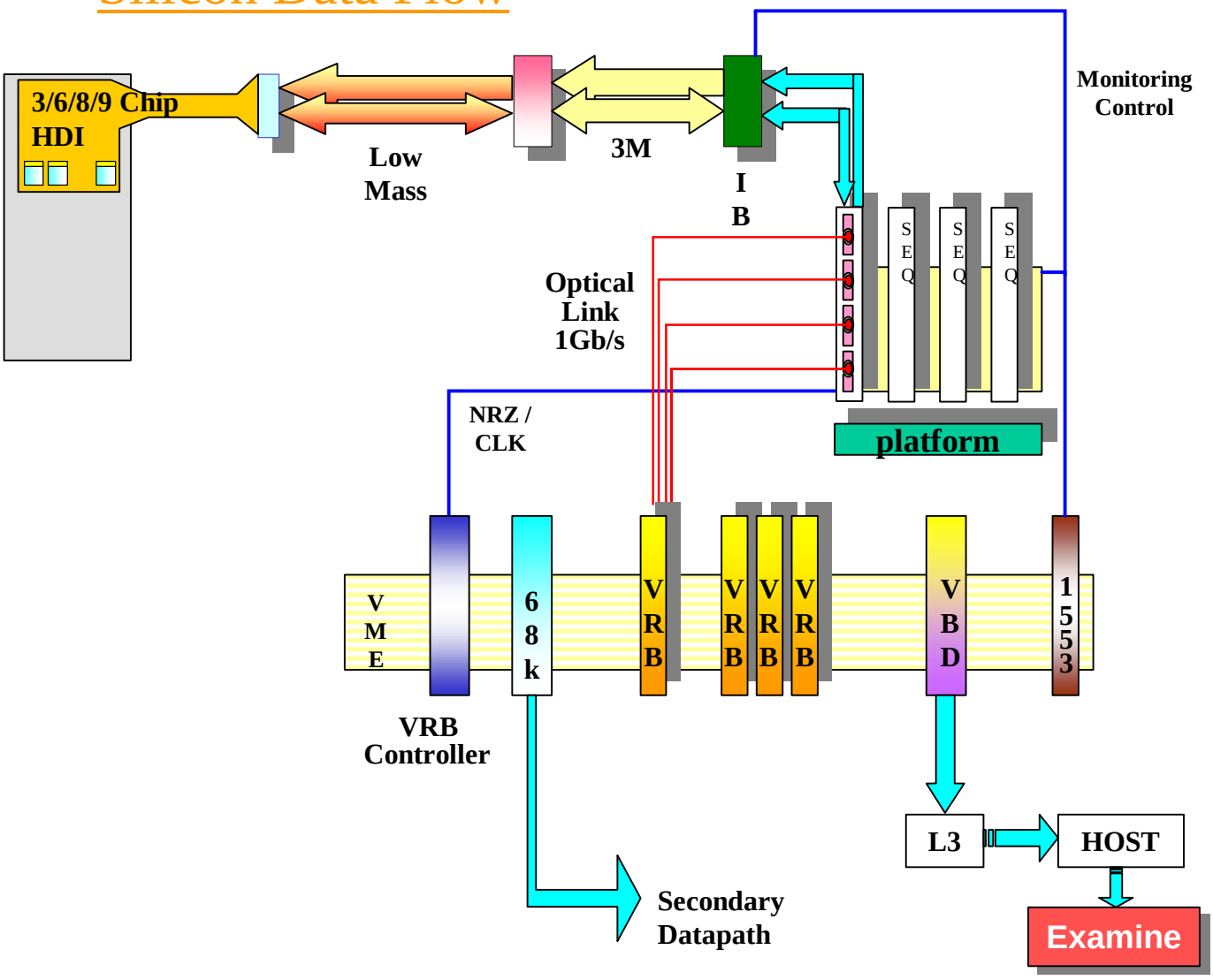
The silicon facility has to become a production line. To pull this off, ~10 additional dedicated people are needed, 2 per subdetector type, with staggered hours. Technician help is available >12 hrs per day.

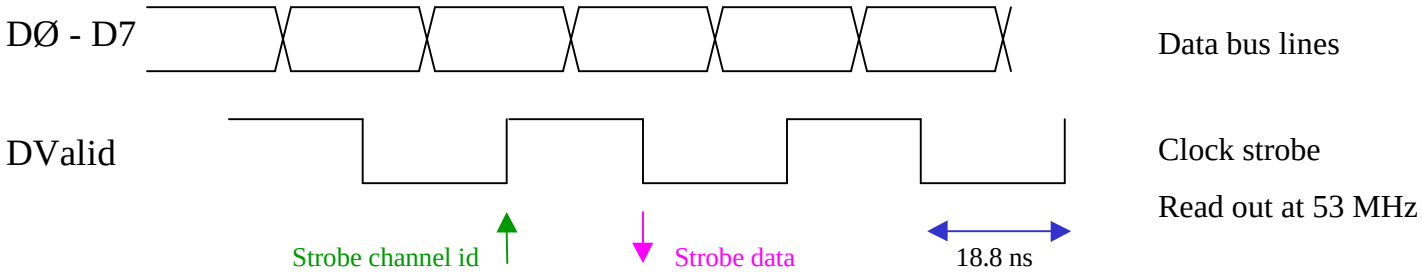
Silicon Read Out

- Complete read out system in final read out configuration installed in clean room in Lab C
- Goals:
  - Ensure data integrity at the level of 10^{14} - 10^{15}, i.e allow for loss of 1 bit in 10^{14} - 10^{15} bits transferred (10^{13} error rate = 1 non-fatal error every 30 minutes)
  - Provide adequate operating margin for device
  - ... ...
- Mode of operation: checksum mode in L3 node:
  - SVX chips downloaded to read out set data value
  - All channels read out; data constant
  - Calculate checksum (sum of all bits) in VBD
  - Data transferred to L3 node; checksum compared
  - If checksum different: read in and analyze event



Silicon Data Flow





DØ: 1M channel readout system @ 5% occupancy at 1kHz trigger rate: 10^{10} bits/s or the equivalent of 312 MHz 32 bit processing. At 10^{15}: 1 error/day

Intel: Pentium Processor, 400 MHz, 32 bit. Most simple instruction (move) takes ~ 4 clock cycles; 100 MHz equivalent.

First Step to Barrel Assembly and Read Out

- Currently available 6 low mass cables and able to read out (though with persistent bottom neighbor problem)
- Will move to 6+6 ladder setup in spare Be support structure and exercise full read out system, DAQ, L3 and on/offline software, controls and monitoring
- First pass at cosmics end of January

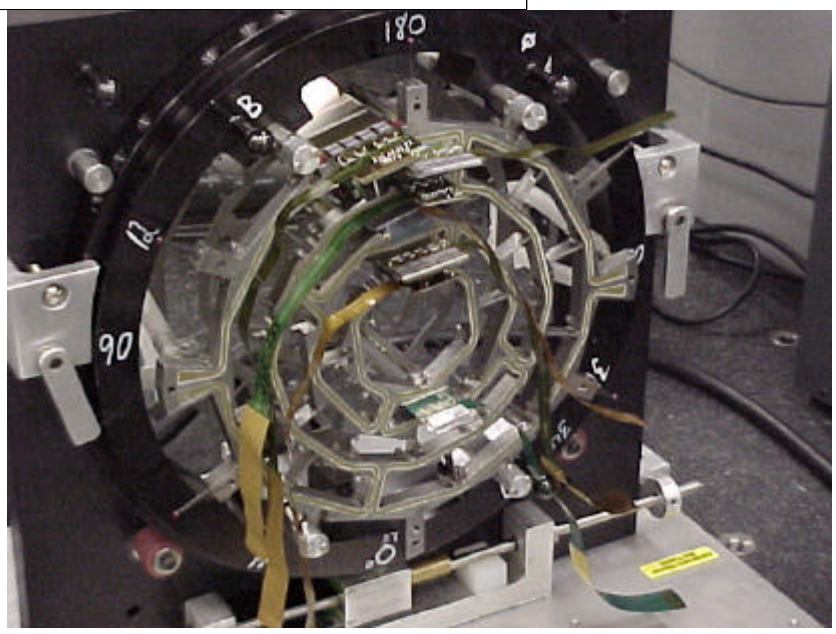
Title:
C:\Silicon\Cables\10%test2.eps
Creator:
AutoCAD PSOUT
Preview:
This EPS picture was not saved with a preview included in it.
Comment:
This EPS picture will print to a PostScript printer, but not to other types of printers.

Array of 4 scintillator counters form external trigger

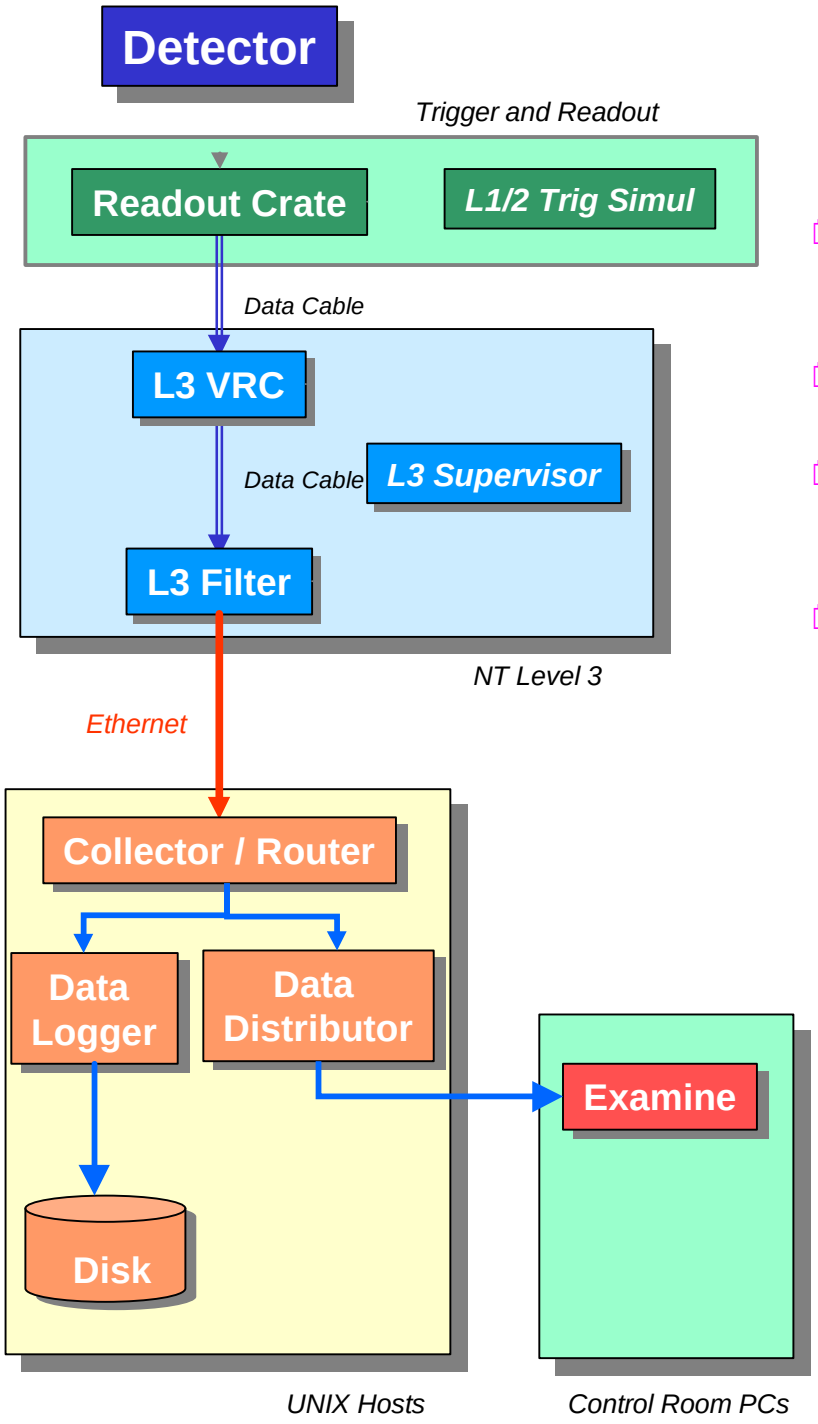
Momentum analyzing steel, $p_T^{\mu} > 2$ GeV/c

Data Rate ~ 1 cosmic/min

Ladder installation in progress



Data Acquisition

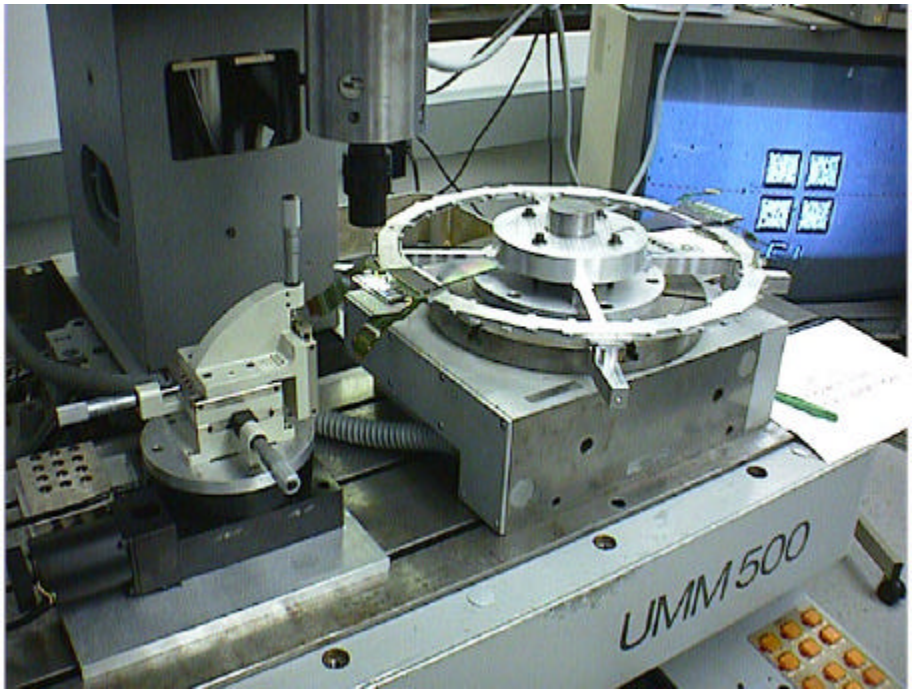


- All pieces to exercise full data acquisition chain are in place
- Read out to L3 system extensively tested
- Online Examine SMT analysis code tested on raw data
- First pass at full read out with cosmic rays Jan 00

- Will slowly ramp up to enlarge read out and complexity of tools
- L3 Tools: data unpacking, hit finding, track reconstruction

Barrel Assembly and Module Installation

- Ladder Installation being exercised
- Full H Wedge construction and H wedge mounting exercised



- Work on Carbon fiber support cylinder underway
- Work on barrel insertion fixture started
- Cabling and hookup studied
- Dry gas enclosure
- H disk shroud
- ……. A lot of work remaining

Fallback

- The laboratory seems adamant in keeping the March 1, 2001 roll in date
- Moreover, the financial situation is bleak
- The experiments were asked to present fallback plans in case they cannot meet the schedule

- Can silicon meet the schedule?

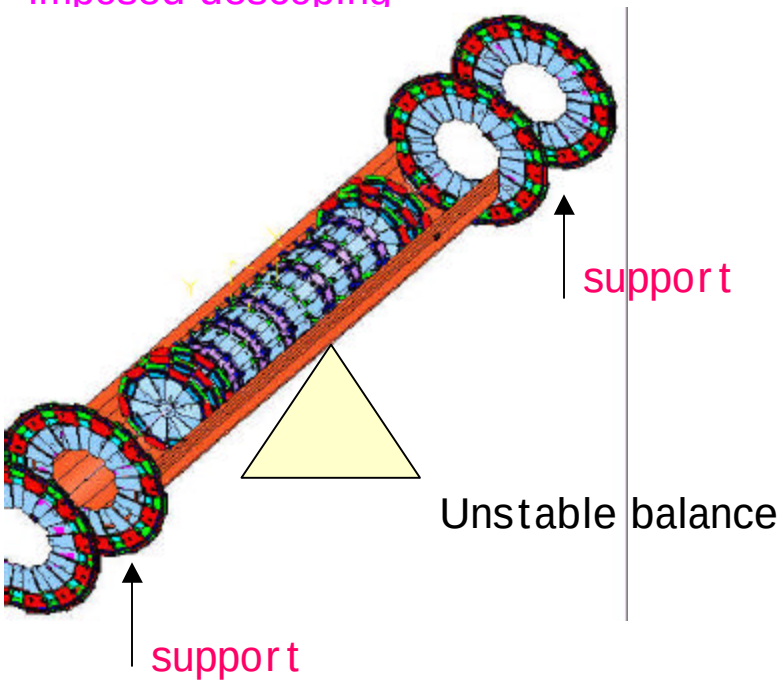
  - ✓ The Si group has been and still is very aggressive in getting the resources needed
  - ✓ (Most of) the infrastructure is in place
  - ✓ Production schedule is aggressive but can be met (barring sensor delivery problems)
  - ✻ The Si group consists of a core of very gifted, dedicated and loyal people who have given and continue to give more than 100%
  - ✻ That core group, however, is stretched too thin
  - ✻ Si has a group of conscientious shifters who prove invaluable

  - – If a group of ~10 dedicated people, full time, for a period of 10 months joins to help in the testing and debugging of detectors and
  - – If additional parts can be purchased

  - – We can have a "soft landing"

Conclusion

- "soft landing":
  - » keep original design
  - » leave "empty slots"
  - » accept lower grade detectors
  - » ... .
- Descoping:
  - » non purchase of parts is default descoping
  - » not shifting priorities is collaboration self-imposed descoping



Note: This is not a plea for help. The problem is staring at us. If the Silicon detector does not get the support, it can (will) fall and could fall hard